Deutsches Institut für
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Discussion Papers

1004

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Berlin, May 2010

IMPRESSUM

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http://www.diw.de

ISSN print edition 1433-0210
ISSN electronic edition 1619-4535

The influence of collusion on price changes: New evidence from major cartel cases

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Abstract

In this paper, we compare the distribution of price changes between collusive and non-collusive periods for ten major cartels. The first moments focus on previous research. We extend the discussion to the third (skewness) and fourth (kurtosis) moments. However, none of the above descriptive statistics can be considered as a robust test allowing a differentiation between competition and cartel. Therefore, we implement the Kolmogorov-Smirnov test. According to our results, 8 out of 10 cartels were successful in controlling the market price for a number of years. The proposed methodology may be used for antitrust screening and regulatory purposes.

Keywords: cartel detection, collusion, competition policy.

JEL classification: L10; L60.

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1 Introduction

The aim of this paper is to develop an empirical method that consistently measures changes in price variation caused by cartel conduct, which can be used by antitrust authorities to screen alleged illegal collusion. The approach can also be useful as an additional technique for establishing damages in antitrust legal proceedings concerning price fixing agreements.

Previous studies have found many different characteristics for identifying collusive behaviour. For example, *Porter and Zona* (1993, 1999) or *Bajari and Ye* (2003) concentrate on some selected bidding markets and demonstrate the difference between collusive and competitive bidding behaviour. For studies that analyze price dispersion in order to detect collusive behaviour, see *Abrantes-Metz et al.* (2006), *Connor* (2005), *Bolotova et al.* (2008) and *Blanckenburg and Geist* (2009). All focus, with different methods, only on the first two moments of price variation (mean and variance). We show that this is inadequate as a means of detecting cartel activity in markets in general, because mean and price variation could be affected, for example, by price trends. To make it clearer, if we do not observe, for example, a substantial increase in prices during the observation period, it does not necessarily mean that there is no cartel. The cartel could have been established during a phase of price reduction as well. Previous methods would fail to detect such cases.

In this paper, we develop appropriate empirical methods and provide evidence on different cartel cases. Therefore, we first assume that cartels need negotiation time to change prices. This holds for the formation phase and for reactions to exogenous shocks.[1] Secondly, established cartels are more likely to react with price raises, in contrast to price reductions, even if they fail their steady-state level. To analyze these hypotheses, we add kurtosis and skewness to the first moments. We expect leptokurtic price change distributions around zero,

[1] For the description of cartel behaviour during the formation-phase see *Blanckenburg and Geist* (2009).

because of delays in price changes during the cartel phase (and therefore more "near-zero changes", in contrast to a competitive benchmark). Furthermore, we expect a positive skewness for the cartel phase, which implies that positive price changes occur relatively more often than negative ones. Additionally, we employ the Kolmogorov-Smirnov test, which is a non-parametric (distribution-free) test comparing two distributions. In fact, the Kolmogorov–Smirnov D-statistic measures a distance between the empirical distribution functions of two samples.

Hence, antitrust authorities may be able to detect cartels, due to specifics in price-change distribution. Adding to previous studies, we analyze numerous cartel cases, which yields new evidence of cartel behaviour. All cartels concern Germany and the relevant organisations were recently prosecuted by the European Commission.

The paper is structured as follows. Firstly, we discuss the theoretical background and hypotheses. Secondly, we present the data we used for our analysis. Thirdly, the empirical results are presented. The final section concludes.

2 Theoretical Background and Hypotheses

Price dispersion has been the focus of both regulatory and academic efforts to identify collusive behaviour.[2] Collusion leads to multiple changes in industry structure and behaviour that are expected to affect price dispersion. First of all – if we assume a cartel operates as a multiplant monopolist – there is an increase in market concentration. *Stigler* (1964) states that price dispersion is ubiquitous, even for homogenous products. It takes place when different suppliers offer different prices for the same good on a certain market. *Carlson and McAfee* (1983), *Fershtman* (1982) and *Dana* (2001) show that price dispersion is greater when

[2] For a good overview of the theoretical and empirical literature on collusion and price dispersion see *Harington* (2005).

industry concentration declines. Furthermore, according to *Connor* (2005), cartels usually fix prices either by announcing list prices to buyers and agreeing to sell only at this price or by agreeing to sell at some lower “floor” (minimum) price or at a “target” (average) price below list. Some cartels also agree to eliminate or restrict discounts, which reduces the variance of prices. There is some empirical support for this hypothesis. *Abrantes-Metz et al.* (2006) examine the effects of a bid-rigging cartel in frozen perch sold to the U.S. Department of Defence. As a result, they find a relatively small difference in price, but a huge difference in variance, when comparing the collusive and competitive regimes. The average price dropped 23% after the conspiracy was detected, but even more significant, the variance of price increased by 145%, compared to the variance during the cartel period. For the lysine cartel, *Bolotova et al*. (2008) find support for the hypotheses that the mean increases and the variance decreases in the cartel period. relative to the pre-cartel and post-cartel periods. Citric acid prices in this study, confirm the mean price hypothesis, but fail to support the variance hypothesis. The variance was even higher, compared to the pre-cartel and post-cartel periods. *Blanckenburg and Geist* (2009) find a significant lower variance in price changes for the cartel period of the German cement industry, compared to the pre- and post-cartel periods.

However, looking at the first two moments might not be sufficient. If there is a trend in prices, for example, because of continuously increasing oil prices, the comparison of means and price variances could be biased by the length of the cartel period and the length of the competitive one. To identify the difference in price setting behaviour – if possible, independently of market characteristics – it is important to compare the entire distribution of price changes.

Therefore, we extend the discussion to the third (skewness) and fourth moment (kurtosis). We assume that cartels change their prices less often, compared to a competitive benchmark. That is because of slow decision processes within a cartel and a certain slackness of cartels regarding adjustments to demand and supply shocks. Price changes have to be negotiated by cartel members, which extends the time of adaptation. Hence,

H1: the distribution of price changes under a cartel has a higher peak around zero.

Furthermore, for the cartel period, it is plausible to assume that price changes are positively correlated with positive demand shocks. Positive demand shocks increase the profit maximizing price and the profit maximizing quantity, and therefore, the cartel members have an incentive to adjust their agreement, which leads to a positive correlation. The adjustments to negative demand shocks are more difficult, because, if cartel members cannot reliably observe the quantities of other members, they are not able to differentiate between demand fluctuations and cheating. Therefore, price decreases after a negative demand shock could be misunderstood by other cartel members as cheating, and may cause price wars (*Green and Porter* 1984, *Abreu et al.* 1986). We assume that cartels increase prices to achieve the monopolistic level and furthermore prefer price increases as adjustments to positive demand shocks. Hence,

H2: the distribution of price changes under a cartel has a higher positive (or less negative) skewness.

The both hypotheses, the expected prices and price changes during cartel and competition are illustrated in Figure 1.

3 Data Description

This study uses monthly price indices from the German Federal Statistical Office (GFSO) of selected industries from 1976-2009. The price indices are calculated by the GFSO using sales-weighted prices of industry members. All used cartel industries are classified by the statistical classification of economic activities in the European Community (NACE). This classification is designed to categorize data.[3] The presented cases were prosecuted by the European antitrust authority.[4] We focus on major cartels containing German market segments. Table 1a lists the analyzed product markets by data. We show the NACE code of these products and in brackets the NACE code of used price data. As is evident, exact data is not available for all cases (e.g. Hydrogen peroxide and perborate; Monochloracetic acid). We indicate the period in which price data is available and point out the cartel-phase within this period. Finally, we show, in Table 1b, the companies involved and the total fines imposed by the European Commission.

4 Empirical Results

In order to detect whether cartel pricing is different from the competition pricing let us first observe the distribution of price changes under competition (continuous black line) compared to the distribution of price changes under cartel (dotted gray line) — see Figures 2a and 2b. One can immediately see that under cartel the price changes are much less volatile and very densely concentrated around the mean.

This impression becomes even stronger when one examines the descriptive statistics of the price changes under competition (Table 2) and cartel (Table 3). Both tables report the first four moments of the corresponding distributions: mean, variance, skewness, and kurtosis.

First, the means of most products both under competition and under cartel appear to be statistically indistinguishable from zero (see Tables 2 and 3). Under competition, there are only three products, for which the null hypothesis of mean equal to 0 can be rejected: Hydrogen peroxide and perborate and Monochloroacetic acid, and Vitamins. Under cartel, the

[3] The NACE-Classification is based on the International Standard Industrial Classification of all Economic Activities (ISIC Rev.2). Parts of ISIC Rev.2 were insufficiently aggregated to represent and monitor European national economics, so any necessary adjustments were made.
[4] http://ec.europa.eu/competition/cartels/cases/cases.html.

null can be rejected only for Vitamins. In all these cases, the means are greater than zero. In addition, when competition and cartel are compared, the means are significantly different only for two products: Hydrogen peroxide and perborate and Monochloroacetic acid at 5% and 1%, correspondingly (see Table 4).

Second, the variances of price changes under cartels seem to be substantially lower than under competition. This applies to all the products. These differences in volatility are significant in all cases, but three: Monochloroacetic acid, Plasterboard, and Synthetic rubbers — as Table 4 shows.

Third, under competition, the distribution of prices changes of four products are skewed: three negatively (Coffee, Plastic industrial bags, and Synthetic rubbers) and one positively (Vitamins) — see Table 2. Under cartel, the distributions of seven products out of ten are skewed: six positively and only one negatively — see Table 3. Negative skewness implies that the negative prices changes occur relatively more often than the positive price changes. These observations are in accordance with what one would have expected, since the cartels are much less inclined to price decreases than the competitive firms.

Fourth, under competition, the distributions of nine products out of ten are leptokurtic implying that they have more acute peaks. The only product, whose distribution has zero excess kurtosis is Marine Hose. Under cartel, only seven distributions out of ten are leptokurtic. The three exceptions are: Hydrogen peroxide and perborate, Monochloroacetic acid, and Plastic industrial bags. In addition, in all cases, save three (Gas insulated switchgear, Marine Hose, and Synthetic rubbers), the distributions of price changes under competition are more acutely peaked than those under cartel. This appears to be at odds with what we saw in Figures 2a and 2b. However, this can be explained by the fact that the distributions depicted in these two figures are not standardized (that is, not divided by the standard deviations) and the price changes under cartel, as we saw above, are significantly less volatile than under competition.

Hence, none of the above descriptive statistics, with an exception perhaps of variance, can be considered as a robust test allowing to distinguish between competition and cartel. Such a test must be in a position to capture the anomalous difference between the competition and cartel distributions, that we saw in Figures 2a and 2b.

Therefore, we decided to employ the Kolmogorov-Smirnov test, which is a non-parametric (distribution-free) test comparing two distributions. In fact, the Kolmogorov–Smirnov D-statistic measures a distance between the empirical distribution functions of two samples. The null hypothesis of the test states that both samples are drawn from the same distribution. Formally, the test statistic is defined as follows:

$$D = \sup_x | F_0(x) - F_1(x) | ,$$

where $F_0(x)$ and $F_1(x)$ are the empirical cumulative distribution functions constructed for each of the two samples being compared. In words, the empirical cumulative distribution functions are compared (as absolute differences of function values) in each point of distribution support and then the largest absolute difference is taken as the Kolmogorov-Smirnov test statistic. When this supremum absolute difference exceeds certain critical value, the null of two samples being drawn from the same distribution is rejected.

The results of the bootstrap version of the traditional Kolmogorov-Smirnov test for the “raw” and demeaned data are reported in Table 4. In the former case the null hypothesis is rejected for all the products. However, when applied to the demeaned data the test fails to reject the null in two products: Hydrogen peroxide and perborate and Monochloroacetic acid. Recall that these two products were the only ones, for which data is available only on a higher aggregate NACE-level (see Table 1a). Obviously, the results are biased because of the data mismatch. Therefore, we can conclude that the distributions of price changes under the competition and under the cartel do differ. These differences can be detected using the Kolmogorov-Smirnov test.

6 Conclusion

Our paper implements the Kolmogorov-Smirnov test to examine the differences in behaviour during collusive and non-collusive periods. We use prices from ten recently discovered conspiracies. The empirical results confirm that 8 out of 10 cartels were successful in controlling the market price for a number of years (for two cartels, no representative data is available).

Following *Harrington* (2005), we argue that negotiations lead to delays in price changes. We confirm this hypothesis empirically and show that the distribution of price changes under a cartel has a higher peak around zero (H1). The results confirm that none of the descriptive statistics, with the possible exception of variance, can be considered as a robust test, which differentiates between competition and cartel. Especially for markets with price trends, the Kolmogorov-Smirnov test is required to detect different price change behaviour. Hence, we are able, in contrast to previous studies (e.g. *Bolotova* 2008), to implement different market structures in the cartel detection analysis. Furthermore, we find some evidence to support the hypothesis that the distribution of price changes under a cartel is positively skewed (H2). In comparison to the competition phases, 7 out of 10 distributions of price changes under a cartel are positively skewed. However, the results should be confirmed by further empirical analysis.

An important direction of further research would be to examine the applicability of proposed screens for collusion. This paper shows how markets with different structures could easily be analysed in a general screening. Additionally, it is necessary to develop methods for generating the initial suspicion of a collusive period. If so, the presented test can be used to substantiate such suspicion.

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Appendix

Table 1a. Descriptive statistics of cartel cases by data periods

Product	NACE (Price Data)	Data Period	N_{all}	Cartel Period	N_{cartel}
Coffee	108311 (108311)	01/1976- 07/2009	402	01/2000- 06/2008	102
Copper Tubes_Copper Fittings	244426 (244426)	01/2000-07/2009	103	05/1988-03/2001	48
Gas insulated switchgear	271210 (271210)	01/1995- 07/2009	175	1988- 2004	113
Hydrogen peroxide and perborate	201363 (2013)	01/1995- 07/2009	175	01/1994- 12/2000	71
Marine Hose	221930 (221930)	01/2000- 07/2009	103	1986- 2007	84
Monochloroacetic acid	20143220 (2014)	01/1995- 07/2009	175	01/1984- 05/1999	52
Plasterboard	236210 (236210)	01/1995- 07/2009	175	1992- 1998	36
Plastic industrial bags	222211 (222211)	01/2000- 07/2009	103	01/1982- 06/2002	29
Synthetic rubbers	201710 (201710)	01/1995- 07/2009	175	05/1996- 11/2002	79
Vitamins	21105 (21105)	01/1985- 07/2009	295	10/1989- 02/1999	113

Table 1b. Descriptive statistics of cartel cases by companies and fines

Product	Companies	Fines[5] (million €)
Coffee	Tchibo, Melitta, Dallmayr	no decision
Copper Tubes_Copper Fittings	Mueller Industries, Austria Buntmetall, Boliden AB, Boliden Cuivre Zinc, Buntmetall Amstetten, Deno Acquisition, Deno Holding Company, Europa Metalli SpA, HME Nederland BV, Halcor SA, IMI Plc, KM Europa Metal AG, Mueller Europe Ltd, Outokumpu Oyj, Tréfimétaux SA, WTC Holding Company, Wieland Werke AG, Yorkshire Copper	222
Gas insulated switchgear	Schneider Electric, ABB Ltd, AREVA T&D AG, AREVA T&D Holding SA, AREVA T&D SA, Alstom, Areva SA, Fuji Electric, Fuji Electric System, Hitachi Europe Ltd, Hitachi Ltd, Japan AE, Mitsubishi Electric, Nuova Magrini G, Siemens AG, Siemens AG Österreich, Siemens Transmis Ltd, Siemens Transmis SA, Toshiba Corporation, VA TECH Transmission	751
Hydrogen peroxide and perborate	Degussa AG, Akzo Nobel Chemicals, Akzo Nobel NV, Arkema SA, Caffaro, Chemoxal, Edison SpA, Eka Chemicals, Elf Aquitaine, FMC Corporation, FMC	388

[5] http://ec.europa.eu/competition/cartels/statistics/statistics.pdf.

Product	**Companies**	**Fines[5] (million €)**
	Foret, KEMIRA OYJ, L'Air Liquide, SNIA, Solvay NV, Solvay Solexis, Total SA	
Marine Hose	Yokohama Rubber Co, Bridgestone, Bridgestone Industri, ContiTech AG, Continental AG, Dunlop Oil & Marine, Manuli Rubber Indust, Parker Hannifin Corp, Parker ITR Srl, Trelleborg AB, Trelleborg Industrie	132
Monochloroace tic acid	Hoechst AG, Akzo Nobel AB, Akzo Nobel Base Chem, Akzo Nobel Chemicals, Akzo Nobel Funct, Akzo Nobel NV, Akzo Nobel Nederland, Arkema SA, Clariant AG, Clariant GmbH, Eka Chemicals, Elf Aquitaine	217
Plasterboard	BPB, Gyproc Benelux, Knauf W.G. KG, Lafarge SA	478
Plastic industrial bags	UPM-Kymmene Oyj, Armando Álvarez SA, BPI, Bernay Film Plastiqu, Bischof + Klein FR, Bischof + Klein GmbH, Bonar Technical Fabr, Cofira-Sac SA, Combipac BV, FL Smidth & Co A/S, FLS Plast A/S, Fardem Packaging BV, Groupe Gascogne, JM Gesellschaft, KV Stempher CV, Kendrion NV, Low & Bonar plc, Nordenia IAG, Nordfolien GmbH, Plásticos Españoles, RKW, Sachsa Verpackung, Stempher BV, Trioplast Industrier, Trioplast Wittenheim	290
Synthetic rubbers	Bayer AG, DOW Deutschland Inc, Dow Chemical Company, Dow Deutschland, Dow Europe GmbH, Eni SpA, Kaucuk as, Polimeri Europa SpA, Shell NL Chemie BV, Shell Nederland BV, Shell Petroleum NV, Trade-Stomil Ltd, Unipetrol as	519
Vitamins	BASF AG, Aventis SA, Daiichi, Eisai Co Ltd, F. Hoffmann-La Roche, Kongo Chemical Co, Lonza AG, Merck KGaA, Solvay Pharmaceutic, Sumika Fine Chemical, Sumitomo Chemical Co, Takeda Chemical Ind, Tanabe Seiyaku Co	855

Table 2. Descriptive statistics of price changes in case of competition

Product	Mean		Variance	Skewness		Kurtosis	
	statistic	p-value	statistic	statistic	p-value	statistic	p-value
Coffee	0.045	0.735	5.361	-0.773***	0.001	8.476***	0.000
Copper Tubes_Copper Fittings	0.915	0.251	41.149	0.580	0.188	5.824***	0.002
Gas insulated switchgear	0.061	0.556	0.654	0.439	0.324	4.460**	0.033
Hydrogen peroxide and perborate	0.352**	0.030	2.630	-0.041	0.904	4.669***	0.009
Marine Hose	0.281	0.258	1.775	-0.241	0.676	3.611	0.227
Monochloroacetic acid	0.337**	0.037	3.111	0.191	0.550	5.013***	0.002
Plasterboard	-0.071	0.653	3.375	-0.415	0.182	6.454***	0.000
Plastic industrial bags	-0.065	0.784	4.767	-0.947**	0.026	6.552***	0.000
Synthetic rubbers	0.249	0.155	2.848	-1.153***	0.007	10.517***	0.000
Vitamins	0.164**	0.033	1.044	3.028***	0.000	21.045***	0.000

Note: significance level: *** 0.01, ** 0.05, *0.1

Table 3. Descriptive statistics of price changes in case of cartel

Product	Mean		Variance	Skewness		Kurtosis	
	statistic	p-value		statistic	p-value	statistic	p-value
Coffee	0.090	0.269	0.664	1.164***	0.005	7.261***	0.000
Copper Tubes_Copper Fittings	-0.023	0.908	1.851	1.274**	0.028	5.293**	0.010
Gas insulated switchgear	-0.066	0.192	0.281	-0.594*	0.093	10.910***	0.000
Hydrogen peroxide and perborate	-0.081	0.576	1.452	0.115	0.779	3.604	0.194
Marine Hose	0.094	0.421	1.106	3.250***	0.000	27.719***	0.000
Monochloroacetic acid	-0.467**	0.033	2.258	0.305	0.520	3.296	0.392
Plasterboard	-0.089	0.741	2.399	1.287**	0.046	5.814***	0.007
Plastic industrial bags	0.089	0.238	0.148	0.375	0.536	2.918	0.684
Synthetic rubbers	0.015	0.932	2.488	3.471***	0.000	24.433***	0.000
Vitamins	0.126***	0.000	0.107	1.226***	0.002	6.523***	0.000

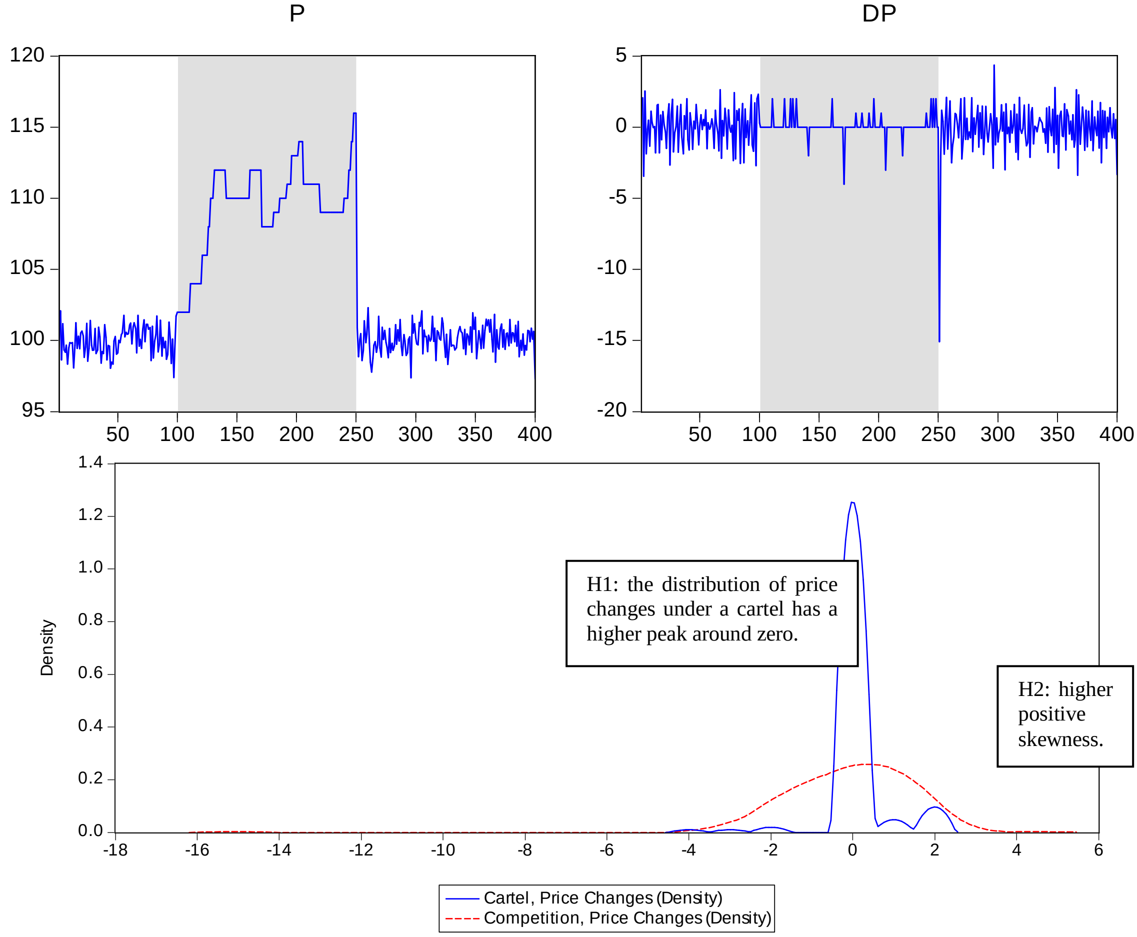
Note: significance level: *** 0.01, ** 0.05, *0.1

Table 4. Comparison of price change distributions in case of competition and that of cartel

Product	Mean equality test[1,3]		Variance equality test[1,3]		Kolmogorov-Smirnov test[3]		Kolmogorov-Smirnov test[3] (demeaned data)	
	t-statistic	p-value	F-statistic	p-value	D-statistic	p-value	D-statistic	p-value
Coffee	-0.287	0.775	8.018***	0.000	0.135**	0.045	0.221***	0.000
Copper Tubes_Copper Fittings	1.152	0.253	22.086***	0.000	0.348***	0.000	0.241*	0.051
Gas insulated switchgear	1.107	0.271	2.346***	0.000	0.205**	0.019	0.363***	0.000
Hydrogen peroxide and perborate	2.008**	0.046	1.803**	0.010	0.204**	0.027	0.118	0.487
Marine Hose	0.693	0.492	1.639*	0.083	0.210**	0.077	0.452***	0.000
Monochloroacetic acid	3.025***	0.003	1.362	0.217	0.298***	0.003	0.083	0.897
Plasterboard	0.059	0.953	1.377	0.279	0.260***	0.021	0.260**	0.032
Plastic industrial bags	-0.622	0.535	31.403***	0.000	0.266**	0.048	0.312**	0.016
Synthetic rubbers	0.940	0.349	1.142	0.546	0.263***	0.002	0.176*	0.087
Vitamins	0.467	0.641	9.686***	0.000	0.203***	0.000	0.574***	0.000

Notes: significance level: *** 0.01, ** 0.05, *0.1
[1] Welch two-sample test
[2] F-test for comparison of two variances
[3] H_0: no cartel

Figure 1. Simulation of cartel (shaded) and competition prices, price changes and density of price changes



Note: Simulation of prices during i) Competition phase: $N_{1\text{-}100,250\text{-}400}(\mu=100;\sigma^2=6{,}25)$. ii) Cartel Formation $Z_{100\text{-}140}$(stepwise raising prices). iii) Cartel Phase $Z_{141\text{-}250}$(price reaction with lag)

Figure 2a. Distributions of price changes during cartel and no cartel phase

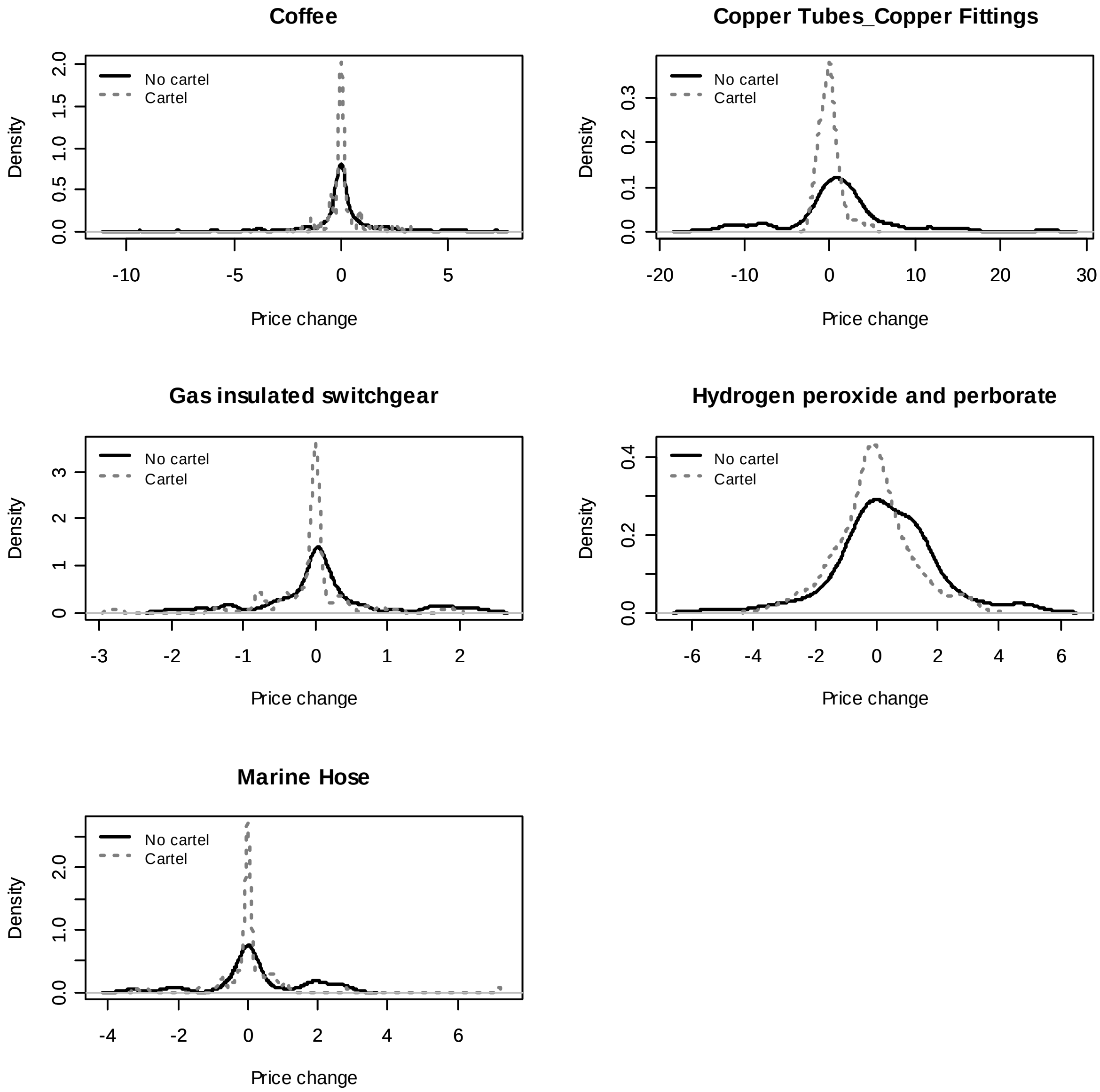


Figure 2b. Distributions of price changes during cartel and no cartel phase